

**UNITED STATES PATENT APPLICATION FOR:**

**SPLICE FOR OPTICAL CABLE**

**INVENTORS:**

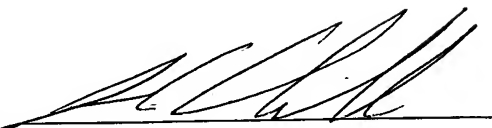
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**CERTIFICATION OF MAILING UNDER 37 C.F.R. 1.10**

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## **SPLICE FOR OPTICAL CABLE**

### **BACKGROUND OF THE INVENTION**

#### **Field of the Invention**

[0001] Embodiments of the invention generally relate to a splice for an optical cable. More particularly, the invention relates to a method and assembly for securing a spliced section of the optical cable.

#### **Description of the Related Art**

[0002] Optical sensors used in harsh environments such as within a wellbore of an oil or gas well communicate readings from within the wellbore to optical signal processing equipment located at the surface. Surface equipment transmits optical signals to the downhole optical sensors via optical cables which transmit return optical signals to an optical signal processor at the surface. The optical cables may run down the outer surface of one of the tubular strings in the wellbore such as production tubing and clamp thereto at intervals as is known in the art. Since the optical cable is exposed to the harsh effects of chemicals, high pressures, and high temperatures, the optical cables used in harsh environments typically consist of multiple layers. For example, these optical cables may have two concentric metal or alloy tubes disposed around an optical waveguide or fiber that transmits the optical signals.

[0003] A fusion splice between the ends of two fibers permits repairing a damaged section of the optical cable, coupling the optical cable to the optical sensor or surface equipment, or adding an additional length of optical cable. However, shifting of the concentric tubes or fibers therein relative to each other due to tensile loads or thermal expansion can damage the fiber that extends from the end of the optical cable. Thus, the components of the optical cable are typically secured to one another at the optical cable ends or termination points in an effort to prevent such relative movement. Further, a fusion splice creates a weak point in the fiber. A virgin fiber can accept approximately a 700,000 psi dynamic tensile load before breaking while the fiber at the splice can accept only approximately a 150,000 psi

dynamic tensile load before breaking. This weakening of the fiber can effect long-term fiber reliability even under low static tensile loads. Therefore, tension on the fiber at the fusion splice must be isolated from tension forces applied to the rest of the fiber and optical cable.

[0004] A conventional method for preparing an optical cable for splicing is a complex and time consuming process. The previous method utilized roller crimping of the optical cable which could take at least an hour to prepare a single optical cable end due to the need for the operator to continually check the depth of the crimp. Even with such constant care, roller crimping subjects the process to operator variability. Further, roller crimping thins the outer coaxial tube wall making it subject to breaking and subsequent bond failure. A member crimped directly to the fiber in the previous method can cause attenuation or power loss in the fiber, especially in small (*e.g.* one eighth inch diameter) optical cable that has a thin buffer layer surrounding the fiber. Benefits of small diameter cable such as increased length of cable per spool, ease in handling, flexibility without kinking, and lower cost make small diameter cable preferable over larger diameter optical cable for many applications.

[0005] Therefore, there exists a need for a simplified method and assembly that secures a spliced section of any diameter optical fiber cable and fibers within the cable, preferably while eliminating or minimizing attenuation or power loss.

## **SUMMARY OF THE INVENTION**

[0006] The invention generally relates to a method and assembly for terminating an end of an optical cable such that coaxial tubes of the cable and fibers therein are all prevented from moving relative to one another. For some embodiments, the coaxial tubes crimp together by a mechanical crimp that compresses the outer tube onto the inner tube without roller crimping. A fiber retention subassembly crimps to one of the coaxial tubes, and an adhesive fills the fiber retention subassembly, thereby fixing the fibers therein and isolating tension from the ends of the fibers that extend from the fiber retention subassembly. The ends of the fibers of the optical cable connect with fibers of another optical cable or device by a fusion splice. A splice

cover holds and/or seals the spliced section and prevents relative movement between the optical cables or the optical cable and the device at the spliced section.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

[0007] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0008] Figure 1 is a view of an end of a coaxial cable having an inner tube and armor cut to accept a fiber retention subassembly.

[0009] Figure 2 is a view of the end of the coaxial cable having crimps that secure the inner tube to the armor to provide a prepared cable end.

[0010] Figure 3 is a view of the fiber retention subassembly aligned with the prepared cable end.

[0011] Figure 4 is a view of the fiber retention subassembly positioned on the prepared cable end and crimped in place.

[0012] Figure 5 is a view of the fiber retention subassembly having an adhesive being injected into it to provide a retained fiber cable end.

[0013] Figure 6 is a partial section view of a splice cover slid over a first retained fiber cable end and adjacent a second retained fiber cable end.

[0014] Figure 7 is a view of a fusion splice and recoat of fibers extending from the first and second retained fiber cable ends.

[0015] Figure 8 is a partial section view of the splice cover secured to a portion of both the first and second retained fiber cable ends to provide a completed cable splice.

#### **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT**

[0016] The invention generally relates to a method and assembly for securing a spliced section of an optical cable. Figure 1 illustrates an end of a coaxial cable 100 having fibers 101, an inner tube 102 and armor 104 cut to accept a fiber retention subassembly (shown in Figure 3). While the cable 100 is shown with the inner tube 102, the cable may not require an inner tube (*e.g.* the fibers 101 may be coated directly with a protective material). Therefore, the invention in some embodiments does not include the inner tube 102 of the cable 100. Additionally, the coaxial cable 100 may include a jacket 106 that covers and protects the armor 104. The jacket 106 is a larger diameter covering that may be made of nylon and clamped to downhole tubing. In order to withstand the environment downhole, inner tube 102 and armor 104 may be made of a metal or alloy.

[0017] To prepare the end for splicing, an end portion of the jacket 106 is cut and removed from the end of the coaxial cable 100. An operator can use a knife to cut and remove a long enough portion (*e.g.* six feet) of the jacket 106 such that the jacket 106 does not interfere during the splicing process. Next, a portion of the armor 104 is removed from the end of the coaxial cable 100. The operator can use a standard tube cutter to score the outside of the armor 104, which the operator can then flex to cleave the portion of the armor 104 being stripped. A sufficient length (*e.g.* twenty inches) of armor 104 is stripped from the coaxial cable 100 in order to leave enough fiber to form the splice. Next, the inner tube 102 is stripped from the coaxial cable 100. The inner tube 102 is stripped such that a length (*e.g.* fifteen hundredths inches) of the inner tube 102 extends past the armor 104. In operation, the operator can score the inner tube 102 with a knife file and flex the inner tube 102 to cleave the portion of the inner tube 102 being stripped.

[0018] As shown in Figure 2, mechanical crimps 200 secure the inner tube 102 to the armor 104 to provide a prepared cable end 201. As with all crimps described herein, the operator can produce the crimps 200 using any available mechanical crimping tool that compresses the armor 104. While roller crimping may be used to perform the crimping, this time consuming and more sensitive procedure may not be required. Thus, a crimping tool having die inserts can be used to provide the crimps 200. Depending on the shape of the die inserts of the crimping tool, the crimps 200 may be a hex crimp, a circular crimp, or any other shape. While three crimps 200 are shown positioned along the outside of the armor 104, any number of crimps 200 may be used in succession to create a stronger holding force between the inner tube 102 and the armor 104. Prior to performing the splice or attaching a fiber retention subassembly (shown in Figure 3), the operator may clean the fibers 101 using an alcohol or other solvent to remove any protective greases.

[0019] Figure 3 illustrates a fiber retention subassembly 300 axially aligned with the prepared cable end 201. The fiber retention subassembly 300 includes a protective tube 302, a fill tube 304, and a section of mating armor 306 all concentrically arranged and crimped together by a crimp 308 in the mating armor 306. Preferably, the protective tube 302 is made of polyimide, and the fill tube 304 is made of a translucent or transparent polymer. However, the tubes 302, 304 may be made of any material such as a hard polymer or metal that is capable of withstanding the environment and protecting and securing the fibers 101. As shown, the crimp 308 secures the mating armor 306 at an end of the fill tube 304 such that a portion of the mating armor 306 extends past the end of the fill tube 304. A portion of the protective tube 302 is secured within the fill tube 304 by the crimp 308 while the remainder of the protective tube 302 extends beyond the end of the fill tube 304 that has the mating armor 306 thereon. The fiber retention subassembly 300 may be formed either on location where the coaxial cable 100 is located or manufactured and preassembled offsite.

[0020] Figure 4 shows the fiber retention subassembly 300 positioned on the prepared cable end 201 and crimped in place by a crimp 400. In order to position

the fiber retention subassembly 300 on the prepared cable end 201, the fibers 101 are run through the inner bores of the protective tube 302 (not visible) and the fill tube 304. The portion of the protective tube 302 that extends beyond the fill tube 304 inserts into the inner diameter of the inner tube 102 (not visible) of the prepared cable end 201. In this manner, the protective tube 302 protects the fibers 101 from any burrs on the end of the inner tube 102 along where the inner tube 102 was cut. The mating armor 306 of the fiber retention subassembly 300 butts against the cut end of the armor 104 of the prepared cable end 201 and surrounds the exposed portion of the inner tube 102 of the prepared cable end 201. Thus, the crimp 400 connects the fiber retention subassembly 300 to the prepared cable end 201 by crimping the mating armor 306 against the outside of the inner tube 102 of the prepared cable end 201.

[0021] Figure 5 illustrates an adhesive, shown diagrammatically as arrow 502, injecting into a fill port 500 of the fill tube 304 to provide a retained fiber cable end 501 once the adhesive cures. If the fill tube 304 does not include a fill port 500, the adhesive 502 may inject directly into the exposed end of the fill tube 304. Applying heat or light to the adhesive cures the adhesive and secures the fibers 101 relative to the fill tube 304 that is secured to the prepared cable end 201. Thus, the portions of the fibers 101 that extend from the retained fiber cable end 501 are isolated from forces applied to the fibers opposite the fill tube 304. When the adhesive 502 is photocurable, the fill tube 304 is made of a translucent or transparent material that passes light from an ultra violet (UV) lamp.

[0022] Figure 6 shows a partial section view of a splice cover 600 that protects the spliced fibers and further prevents tension force on the fibers at the splice. In operation, the splice cover 600 slides over a first retained fiber cable end 601 such as the retained fiber cable end 501 described above with reference to Figure 5. The first retained fiber cable end 601 aligns adjacent a second retained fiber cable end 602. The second retained fiber cable end 602 may be a lead from a sensor, instrument, gauge, or connector and may actually be a cable end that has not been prepared as a retained fiber cable end as described herein. As shown in Figure 7, a

fusion splice connects the ends of fibers 701 extending from each cable end 601, 602. Known techniques and commercially available equipment may be utilized to form the fusion splice that connects the ends of the fibers 701. Making the fusion splice generally involves stripping the coating from the fibers, cleaning the fibers, cleaving the fibers to get a flat polished end, precisely aligning and heating the ends to join the fibers, and recoating the fibers along the spliced portion.

[0023] After the fusion splice and recoating of the fibers 701, the splice cover 600 slides across cable ends 601, 602 as illustrated in Figure 8. The splice cover 600 includes a union fitting cut into a first half 801 and a second half 802 with a section of tubing 803 welded between the two halves 801, 802 of the union fitting. Thus, each half 801, 802 of the union provides a compression fitting. The length of the tubing 803 covers the excess fiber necessary for the fusion splicing and permits fiber stowage if necessary. Alternatively, the splice cover 600 may only include the first half 801 of the union welded to the tubing 803 that has an opposite end exposed for subsequent coupling via a weld, thread, or otherwise to a connector or other device. As shown, the splice cover 600 secures to a portion of both the first and second retained fiber cable ends 601, 602 with the compression fittings 801, 802 that tighten against an outside surface of armor 804 of the cable ends 601, 602 to provide a completed cable splice. In this manner, the splice cover 600 holds the armor 804 to prevent relative movement between the cable ends 601, 602 across the fused fibers. The splice cover 600 may additionally seal the stripped portions of the cable ends 601, 602 from the outside environment.

[0024] The lengths of the portions of jacket 106, armor 104, and inner tube 102 that are stripped from the end of the coaxial cable 100 are not fixed and depend on the lengths of the splice cover 600, the fiber retention subassembly 300, the portion of the mating armor 306 of the fiber retention subassembly 300 that extends beyond the fill tube 304, and the length of fiber 101 needed to complete the fusion splice. Thus, the lengths given are only examples for one embodiment.

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[0025] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.